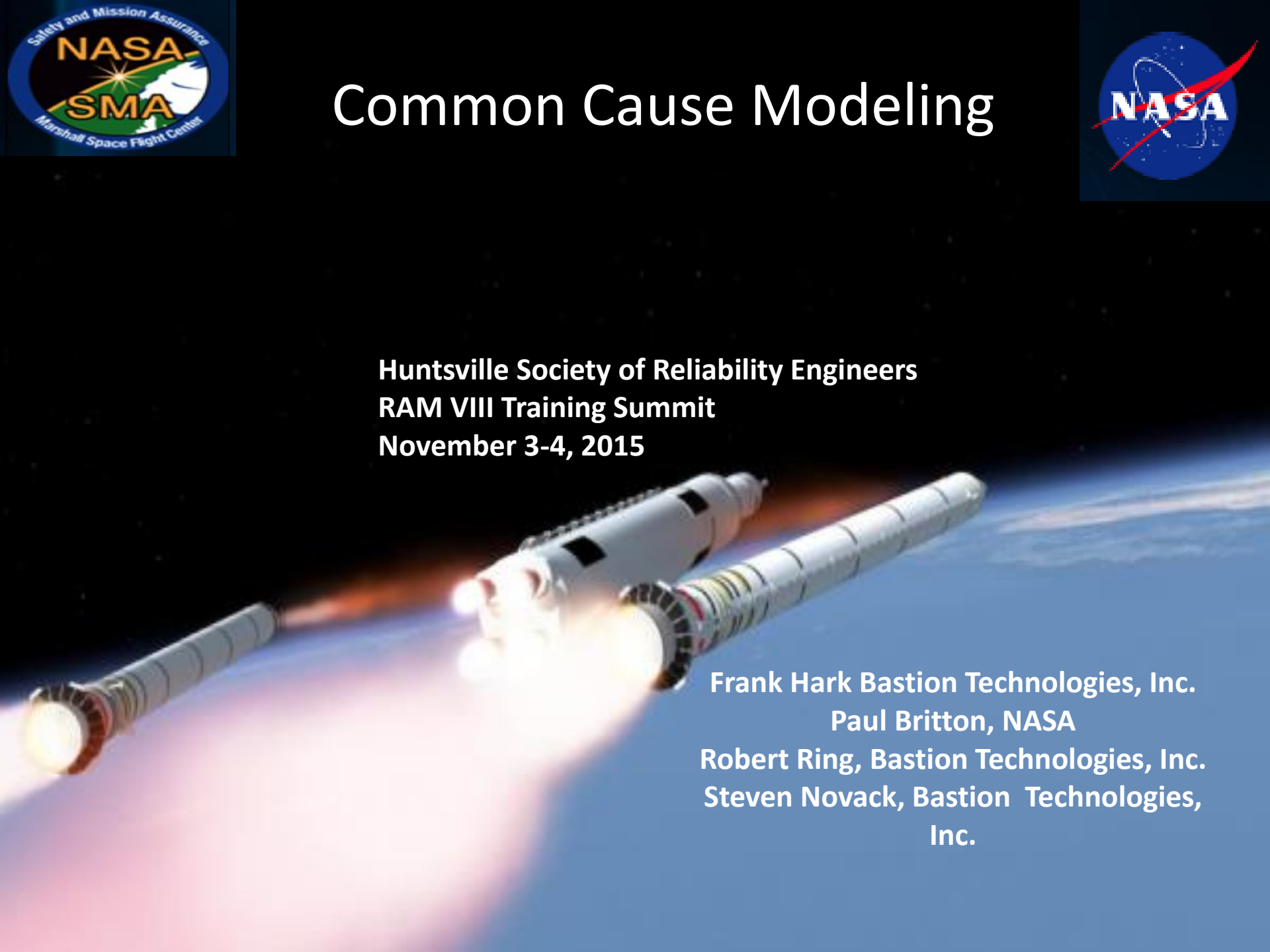
Common Cause Modeling



Huntsville Society of Reliability Engineers
RAM VIII Training Summit
November 3-4, 2015

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Space Launch System

Agenda

- Objective
- Key Definitions
- Calculating Common Cause
- Examples
- Defense against Common Cause
- Impact of varied CCF and abortability
- Response Surface for various CCF Beta
- Takeaways

Objective

- **Common Cause Failures (CCFs) are known and documented phenomenon that limit the benefit of system redundancy as a design approach to achieve high reliability**

- **Because Launch vehicle data is sparse, generic data from the nuclear industry is used to estimate CCF for launch vehicles**

- **This presentation addresses the impact of CCF risk on system reliability and safety**

Key Definitions

- **A common cause failure (CCF) is a failure where:**
  - Two or more items fail within the mission time from a common failure mechanism.

- **Beta Factor is defined as the fraction of the component failures that result in a common cause failure**

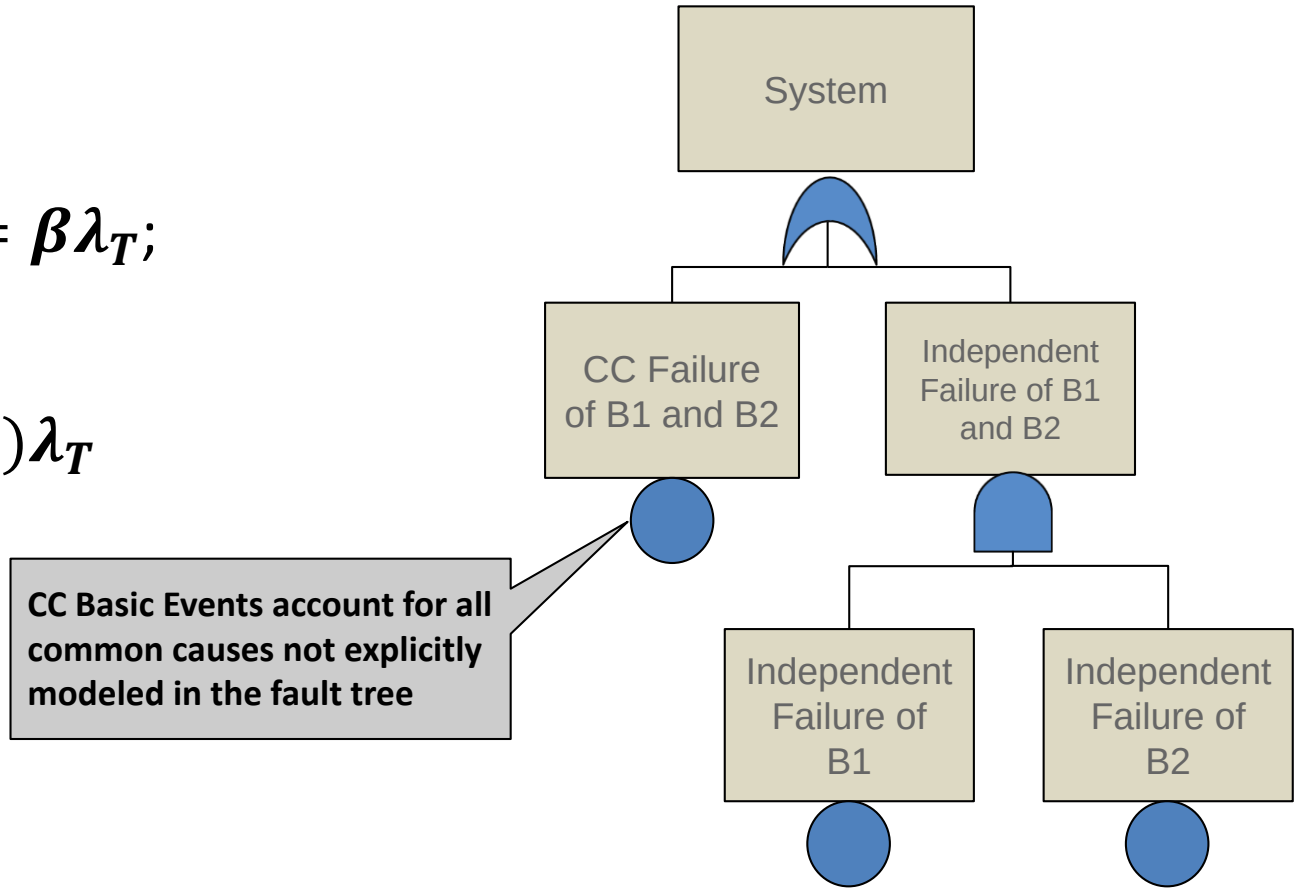
Calculating Common Cause Failure

CCFs may also be viewed as being caused by the presence of two factors:

1. Root or proximate Cause, i.e., the reason (or reasons) for failure of each component that failed in the CCF event, and a
2. Coupling Factor (or factors) that was responsible for the involvement of multiple components.

$$\beta = \frac{\lambda_C}{\lambda_T} \Rightarrow \lambda_C = \beta\lambda_T;$$

$$\lambda_I = (1 - \beta)\lambda_T$$



Examples
(taken from the NASA PRA Guide)

The following are examples of actual CCF events:

- **Hydrazine leaks leading to two APU explosions on Space Shuttle mission STS-9**
- **Multiple engine failures on aircraft (Fokker F27 –1997, 1988; Boeing 747, 1992)**
- **Three hydraulic system failures following Engine # 2 failure on a DC-10, 1989**
- **Failure of all three redundant auxiliary feed-water pumps at Three Mile Island NPP**
- **Failure of two Space Shuttle Main Engine (SSME) controllers on two separate engines when a wire short occurred**
- **Failure of two O-rings, causing hot gas blow-by in a solid rocket booster of Space Shuttle flight 51L**
- **Failure of two redundant circuit boards due to electro-static shock by a technician during replacement of an adjacent unit**
- **A worker accidentally tripping two redundant pumps by placing a ladder near pump motors to paint the ceiling at a nuclear power plant**
- **A maintenance contractor unfamiliar with component configuration putting lubricant in the motor winding of several redundant valves, making them inoperable**
- **Undersized motors purchased from a new vendor causing failure of four redundant cooling fans**
- **Check valves installed backwards, blocking flow in two redundant lines**
- **CCFs may also be viewed as being caused by the presence of two factors:**

Reducing it

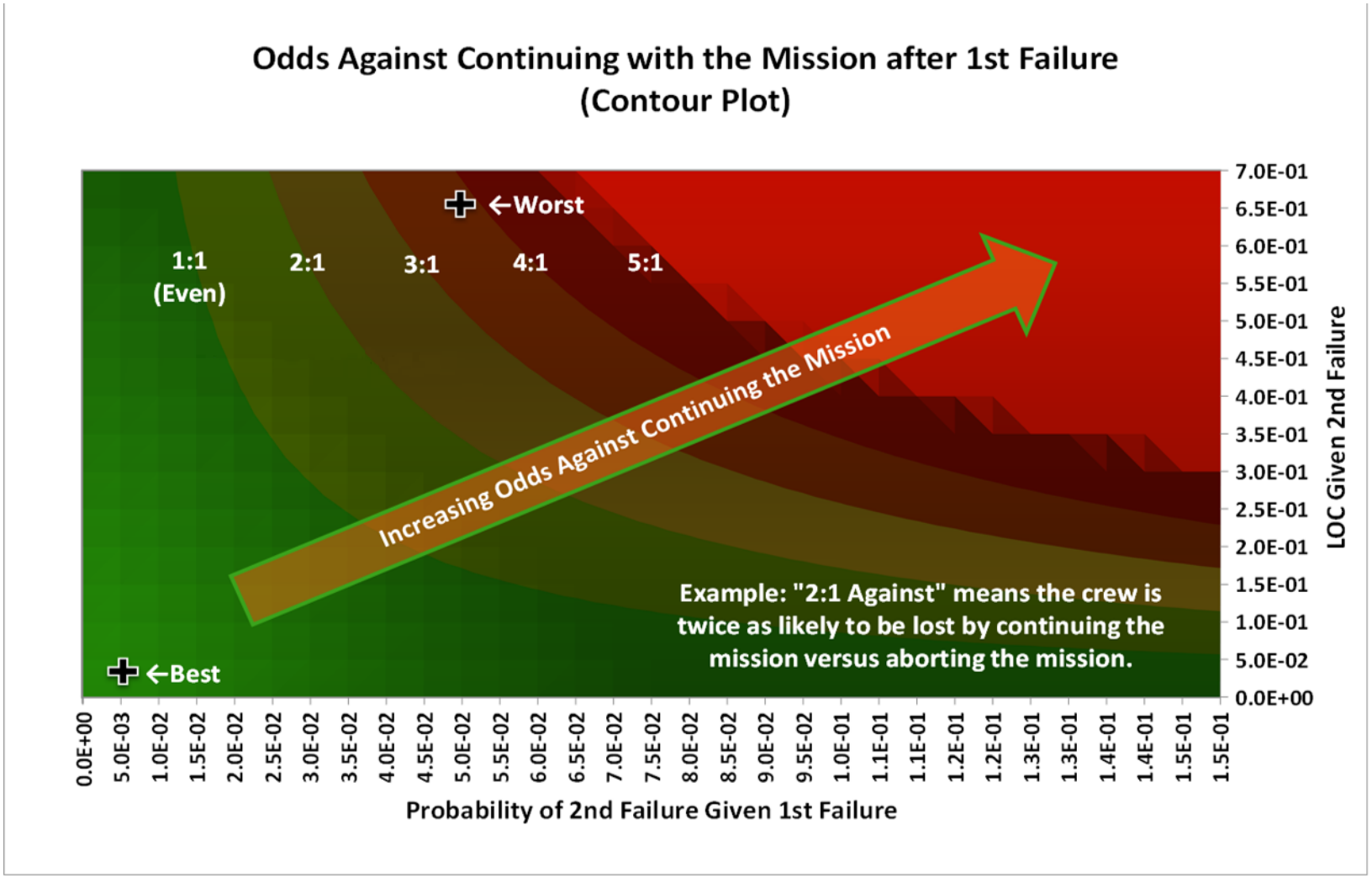
Checklist for reducing common cause categorized into 8 groups

1. Degree of physical separation/segregation
2. Diversity/redundancy (e.g., different technology, design, different maintenance personnel)
3. Complexity/maturity of design/experience
4. Use of assessments/analysis and feedback data
5. Procedures/human interface (e.g., maintenance/testing)
6. Competence/training/safety culture
7. Environmental control (e.g., temperature, humidity, personnel access)
8. Environmental testing

Impact of Varied CCF and Abortability

- **CCF estimate becomes important when trading between a 1 out of 2 system and 1 component fails**
  - **Abort immediately or continue mission**
  - **STS used fail opt/fail safe redundancy**
- **Cost/weight concerns limit some systems to one level of redundancy**
- **What is the benefit of adding an additional level of redundancy**

Response Surface for Various CCF Beta



Takeaways

- **Common cause failure is a known impact to redundant system**
- **Common modeling assumptions may underestimate the real risks**
- **When data is unavailable, it is important to judge the impact of system reliability, safety, and common cause factors over a range of values**

References

1. A. Mosleh et al., “Procedures for Treating Common Cause Failures in Safety and Reliability Studies,” U.S. Nuclear Regulatory Commission and Electric Power Research Institute, NUREG/CR-4780, and EPRI NP-5613.
2. Zitrou A, Bedford T. 2003 Foundations of the UPM common cause model. In: Bedford T Gelder PH. Van, eds. Safety and reliability. Balkema, ESREL 2003; 1769-1775
3. A. Mosleh, D.M. Rasmuson, F.M. Marshall, “Guidelines on Modeling Common-Cause Failures in Probabilistic Risk Assessment,” Office for Analysis and Evaluation of Operational Data, NUREG/CR-5485